Future Integration of Wind in the Energy System

and the role of state-of-art experimental facilities

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Future Integration of Wind in the Energy System
- and the role of state-of-art experimental facilities

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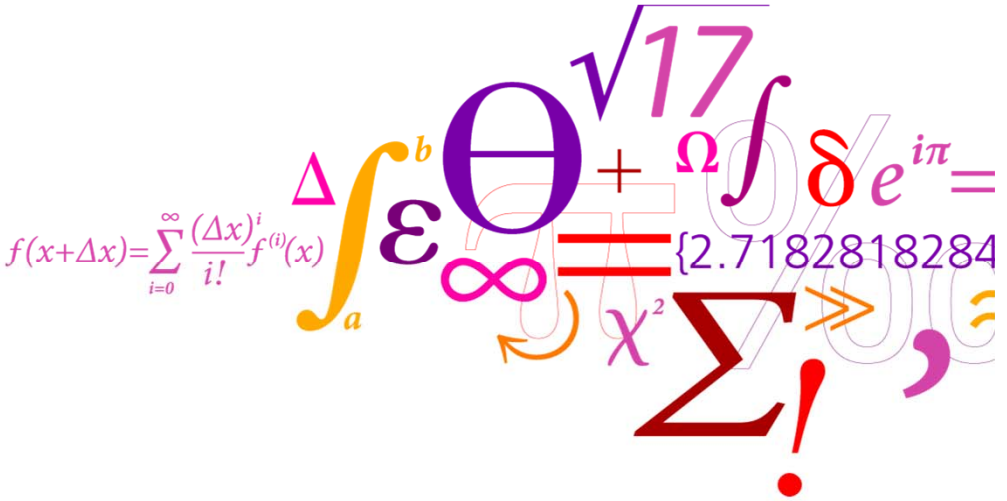
Center for Electric Power and Energy, DTU Elektro

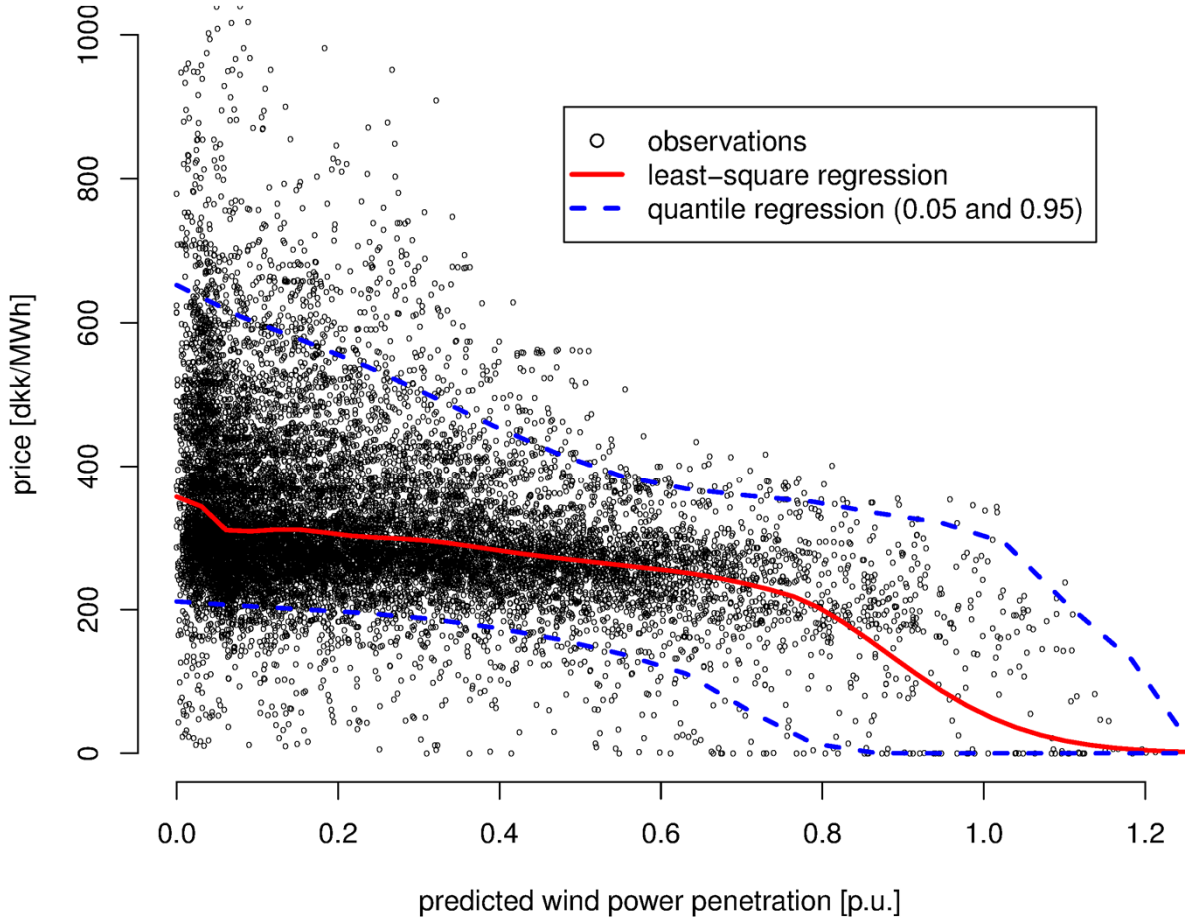
10 September 2014
Grand Opening LORC Nacelle Testing Centre

PowerLabDK

DTU Electrical Engineering
Department of Electrical Engineering



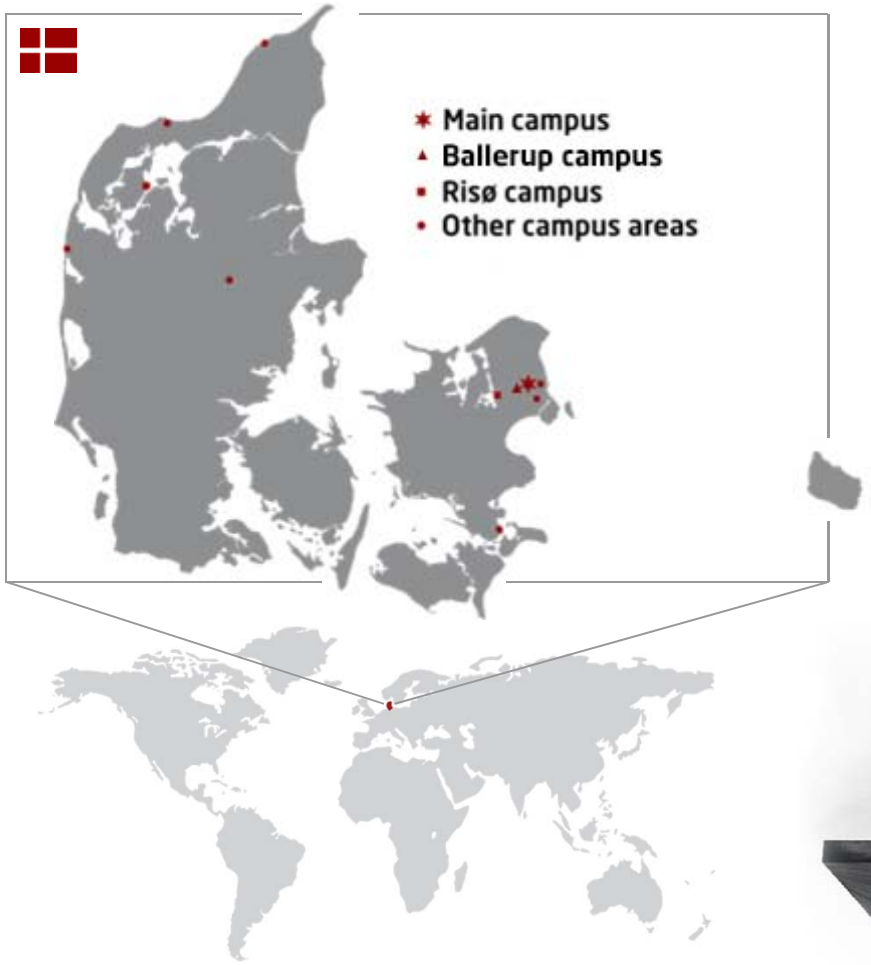
Electricity Markets: Impact of Wind Power on the Nordic Electricity Market



Source: Pinson et. al (2012). IEEE Power & Energy Society General Meeting 2012, San Diego, California, US.

Technical University of Denmark

(founded 1829; first rector H.C. Ørsted)



~1.000 researchers involved in energy R&D

Three energy-focused departments

Five dedicated energy MSc programs, including MSc in Wind Energy

Center for Electric Power and Energy (CEE)
Department of Electrical Engineering

- Development of a reliable, cost efficient and sustainable energy system based on renewable energy

- Approx. 100 staff incl. 30 PhD-students

- Competence areas
  - Electric power components
  - Electric power grids
  - Distributed energy resources and control
  - Energy system operation and management
  - Electricity markets and energy analytics

- Located at Lyngby Campus and Risø Campus

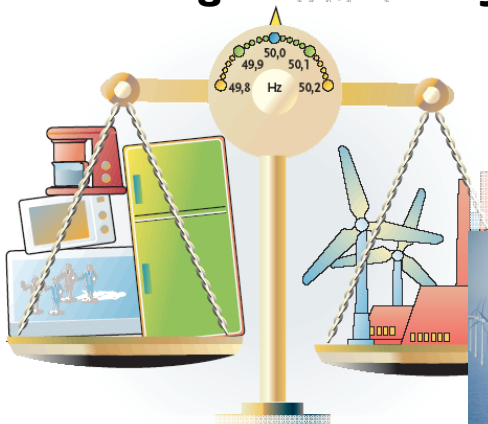
- Bachelor and master programs
  - Electrical Engineering / Electric Energy Technology / Wind Energy / Sustainable Energy

- Strategic partnerships

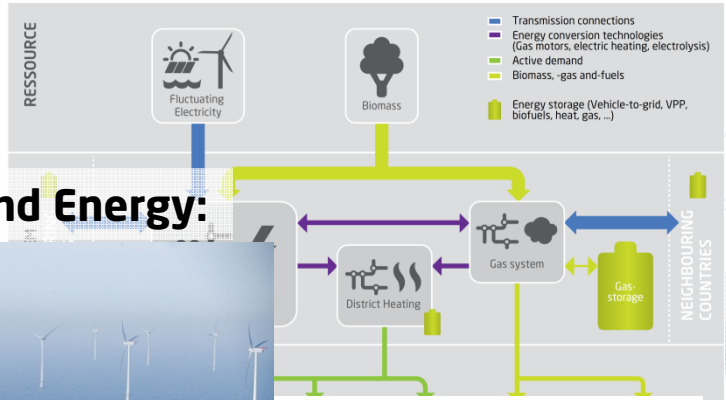
Research Challenge covered by CEE

Development of a reliable, cost-efficient and sustainable energy system based on renewable energy

Balancing the Power System:



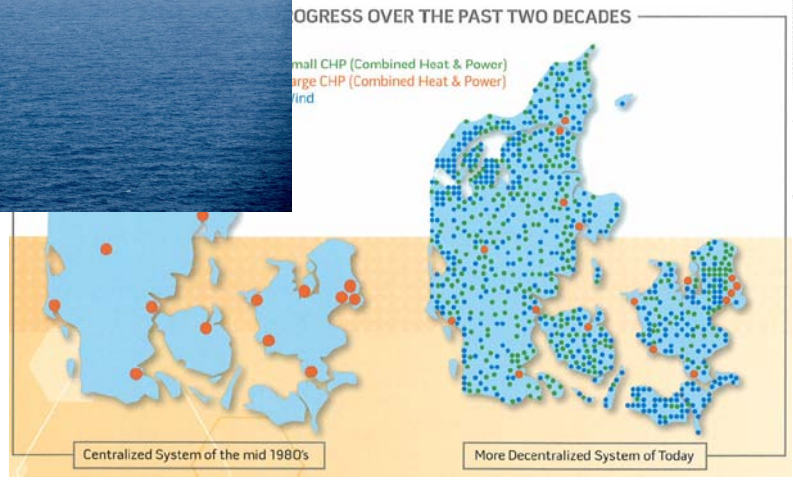
Coherent Integrated Energy System:



Cost Effective Wind Energy:

Stability and Relia

eration Landscape:



Importance of Experimental Facilities for Technology Development, Testing, Demonstration and Training

Past
Jaguar anno 1960

Renew, extend & interconnect

Future
Tesla Roadster, 100% EV, 0-100 km/h in 3 s

Vision: Cutting-edge facilities as driving force for collaboration and groundbreaking new knowledge and innovations.

PowerLabDK

PowerLabDK combines experimental facilities

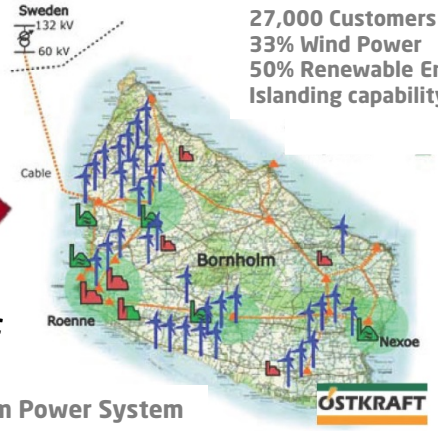
Flexible multi-purpose laboratories

Lyngby & Ballerup Campus

Large-scale test system

Risø Campus

Full-scale Realistic Power System



Bornholm Power System

27,000 Customers
33% Wind Power
50% Renewable Energy
Islanding capability

Stakeholders:

ABB
nkt cables
danskenergi
SIEMENS
DONG energy
VATTENFALL
ENERGINET.DK
IBM

Supported by:

GREEN LABS DK
EUDP

Investment:

18 million Euro

PowerLabDK

High Voltage, High Power and Student Labs

Components in interaction with complex energy systems

www.powerlab.dk

DTU Technical University of Denmark

INGENIØR HØJSKOLEN KØBENHAVN – University College

ØSTKRAFT energi til gode oplevelser

PowerLabDK

Electric Lab

Power and energy technologies for the intelligent grid

www.powerlab.dk

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Intelligent Control Lab

Power system simulation, control and supervision

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SYSLAB and PowerFlexHouse

Intelligent distributed energy system in practice

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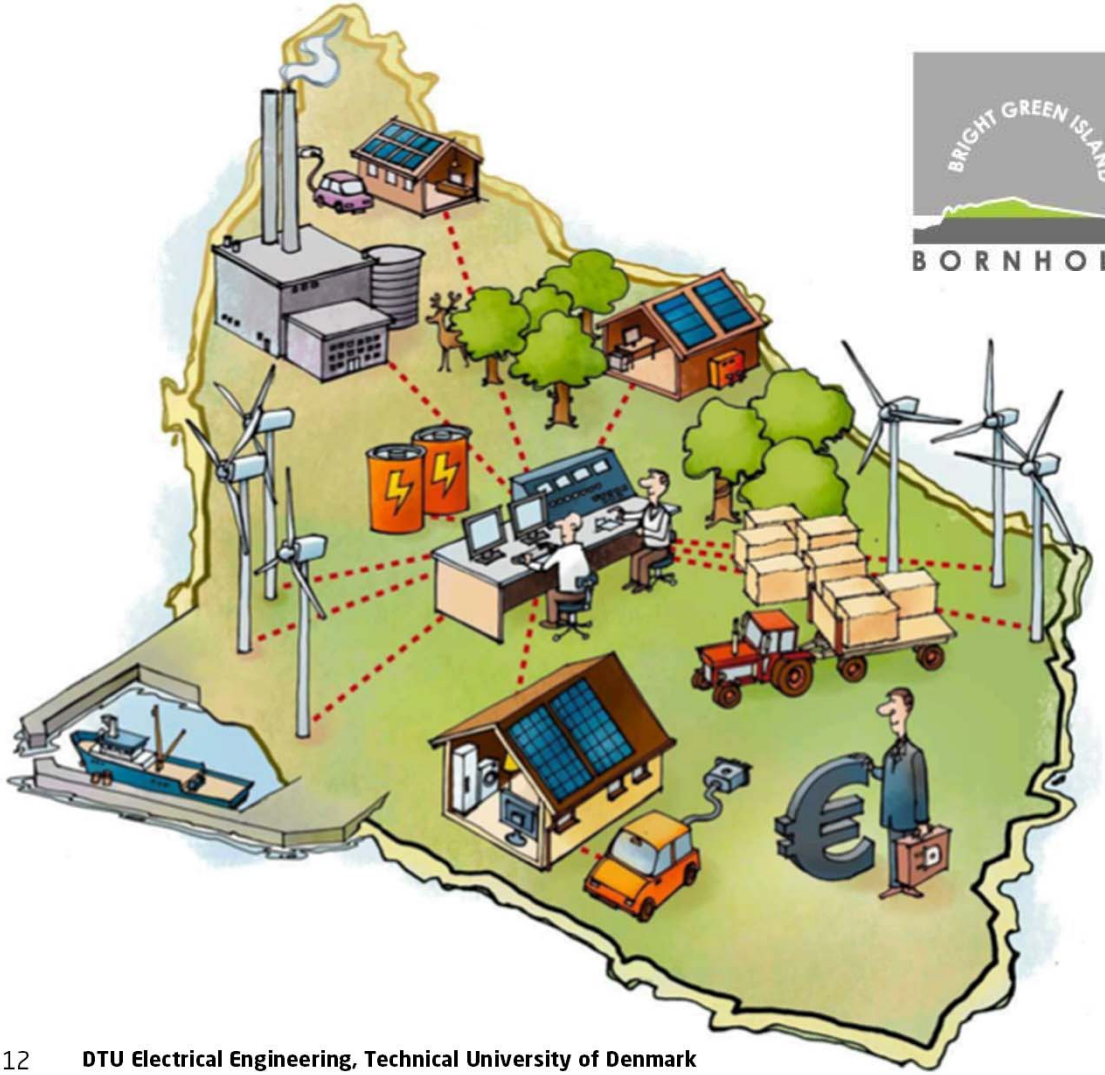
ØSTKRAFT energi til gode oplevelser

Bornholm

Full-scale Living Laboratory with 40,000 Inhabitants and 50% Renewable Energy Penetration



Resources:
- *Wind power*
- *Biomass*
- *Biogas*
- *District heating*
- *Combined heat and power*
- *Solar power*
- *eMobility*
- *Active demand*

Features:
- *Nord Pool market*
- *Islanding capability*

Real-time Digital Simulator (RTDS)

- *A highly specialized digital computer dedicated for real-time dynamic simulation of power systems and interaction with external equipment*
- Europe's most powerful installation: 10 racks w. 80 CPU's, simulation time step 50 µs
- Application
  - Transmission and distribution network analysis
  - Hardware-in-loop verification of equipment under realistic grid conditions
  - Complex system tests with power hardware-in-the-loop (up to 1.2 MW_p)
  - Operator training and control room solutions (operator-in-loop)
- Benefits
  - Shorter development time
  - Short distance from lab to real-life
  - Verification of equipment under multiple realistic scenarios


PowerLabDK

Integrated experiments

www.powerlab.dk

DTU Technical University of Denmark

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ØSTKRAFT energi til gode oplevelser

Off-shore Wind Power Plant with a HVDC Power Transmission

- Different HVDC topologies and their performance
- Development of fault ride though cabability
- Power hardware-in-loop (PHIL) experimental setup in PowerLabDK with converter HW+SW:

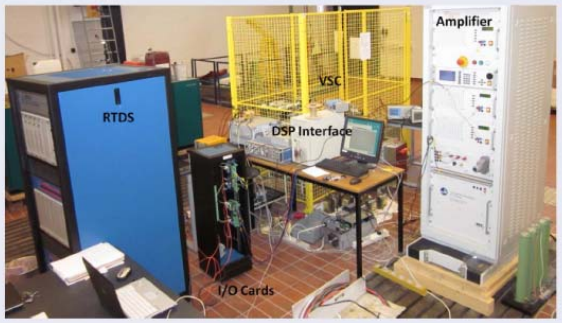
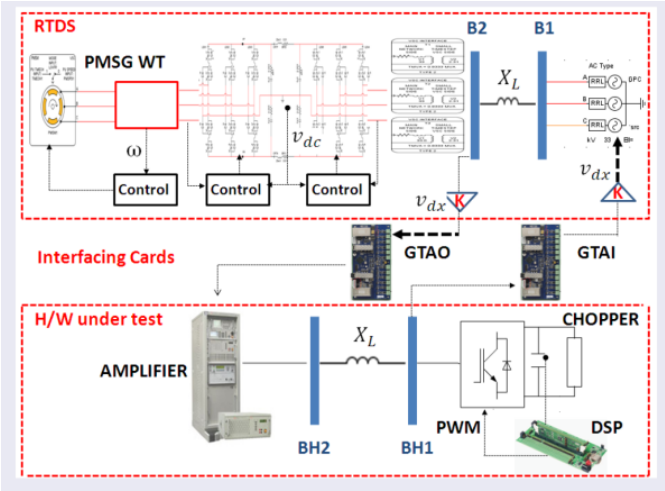


Figure: Picture showing the different components of the implemented PHIL test experiment.

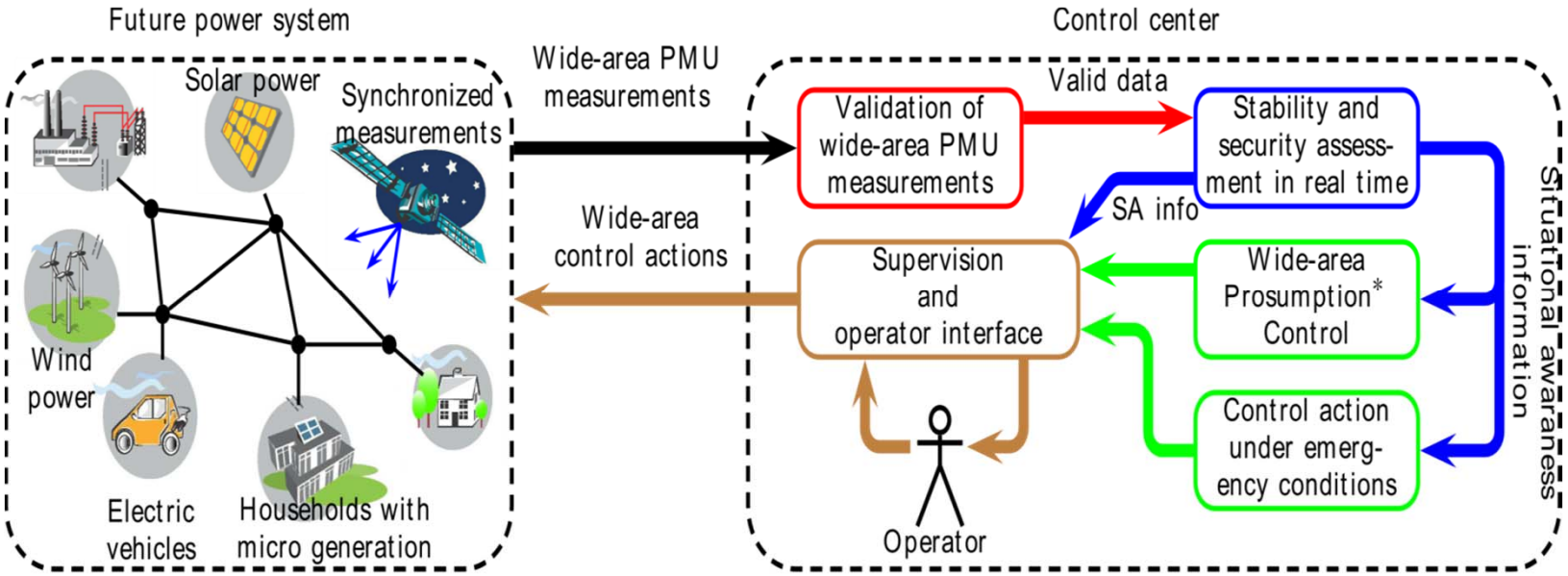


Refs: - Patent, no. US 20120300510 A1.

- R. Sharma et al., Power-Hardware-In-the-Loop (PHIL) Test of VSC-based HVDC connection for Offshore Wind Power Plants (WPPs). *10th International Workshop on Large-Scale Integration of Wind Power into Power Systems*. 2011.

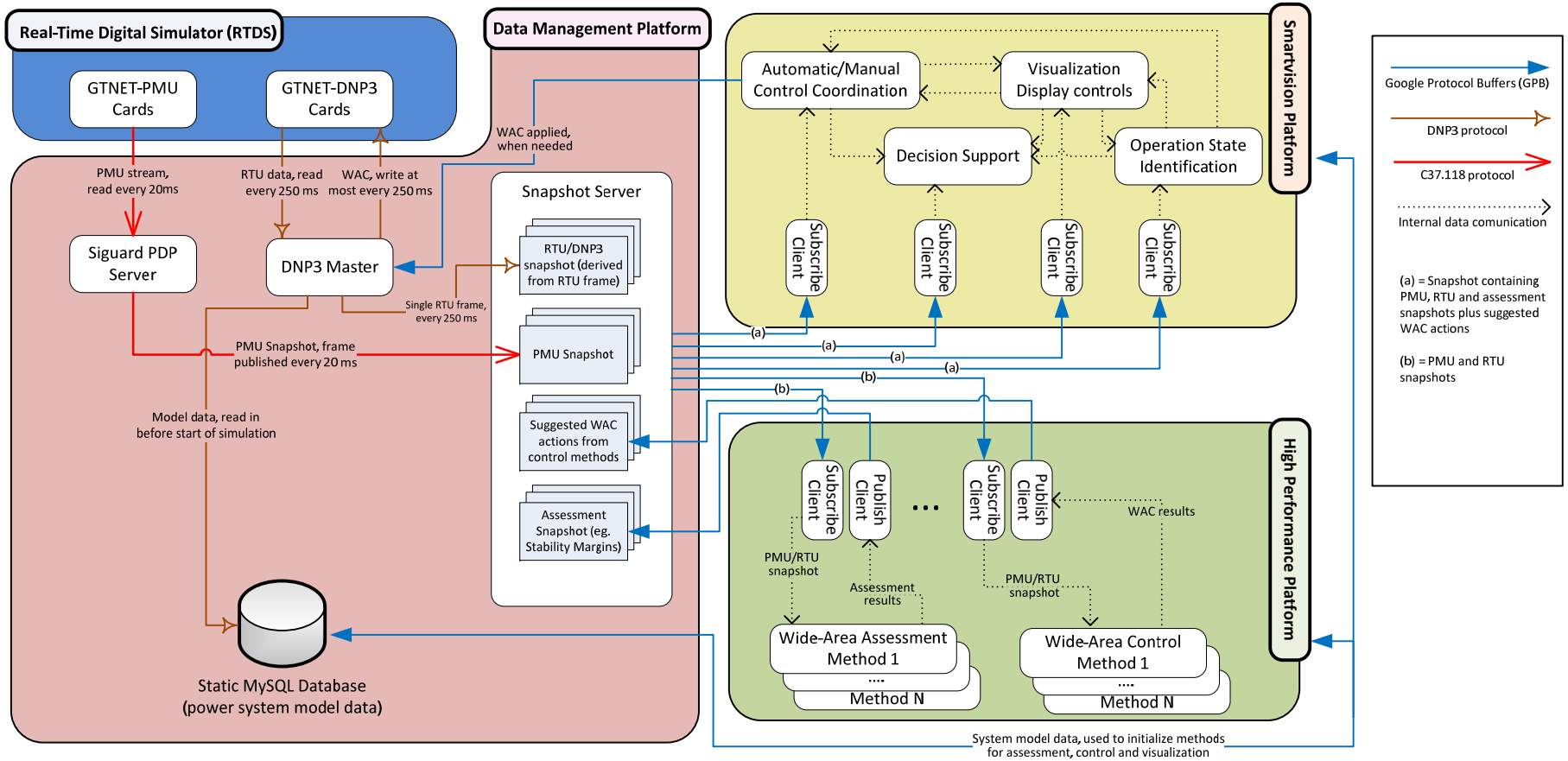
Secure Operation of Sustainable Power Systems (the SOSPO project)

- *How to ensure a secure operation of the future renewable-based power system where the operating point is heavily fluctuating? (Real-time assessment methods.)*

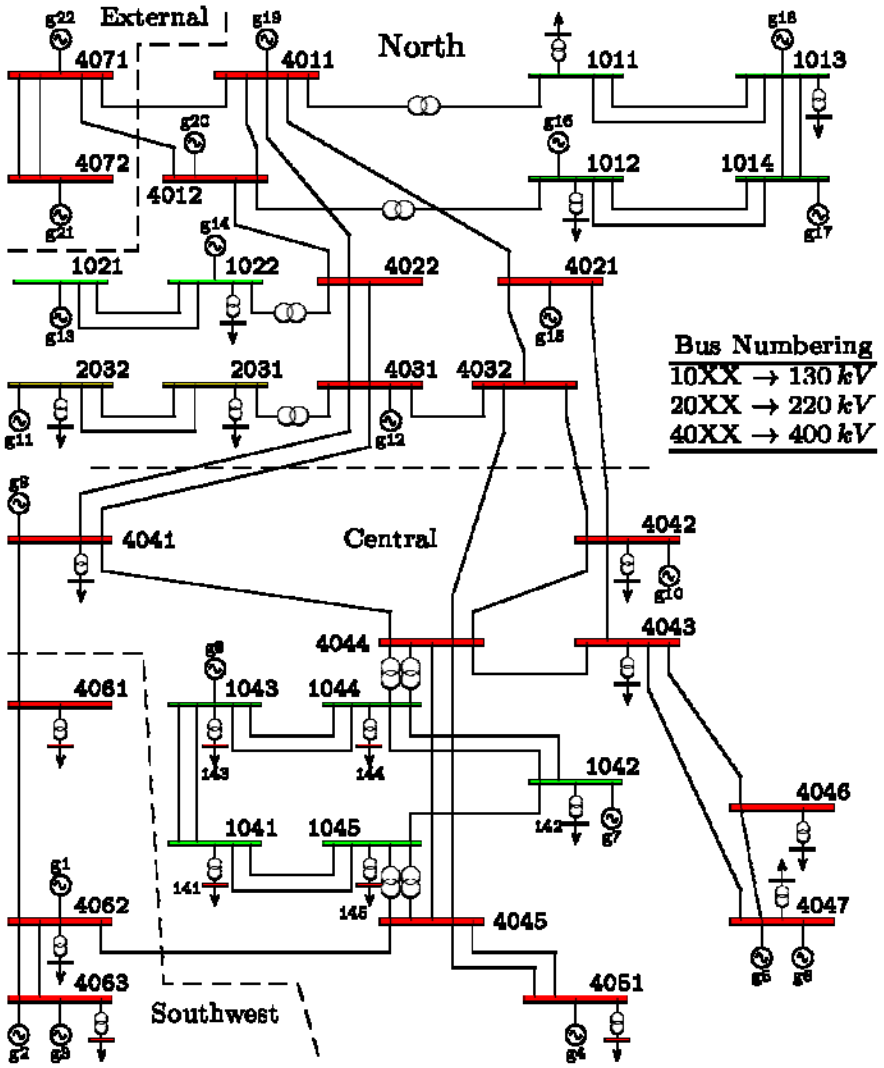


SOSPO SW-Platform

An advanced modular development platform

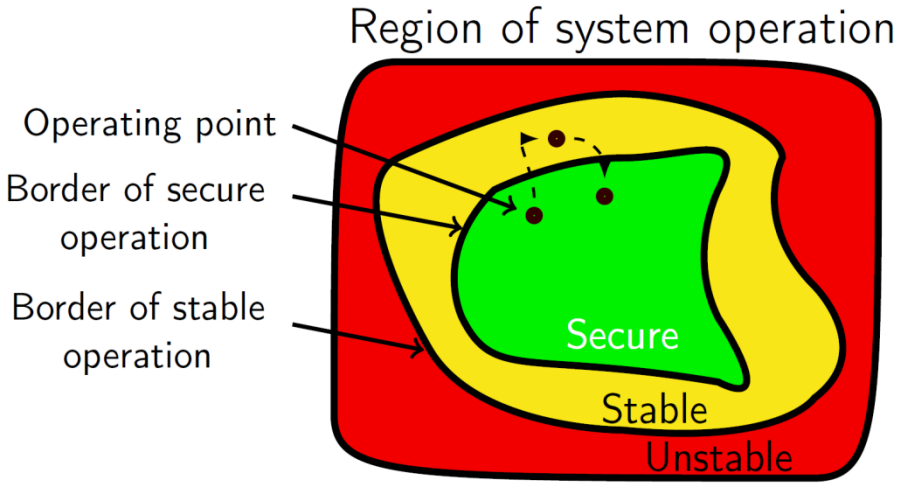


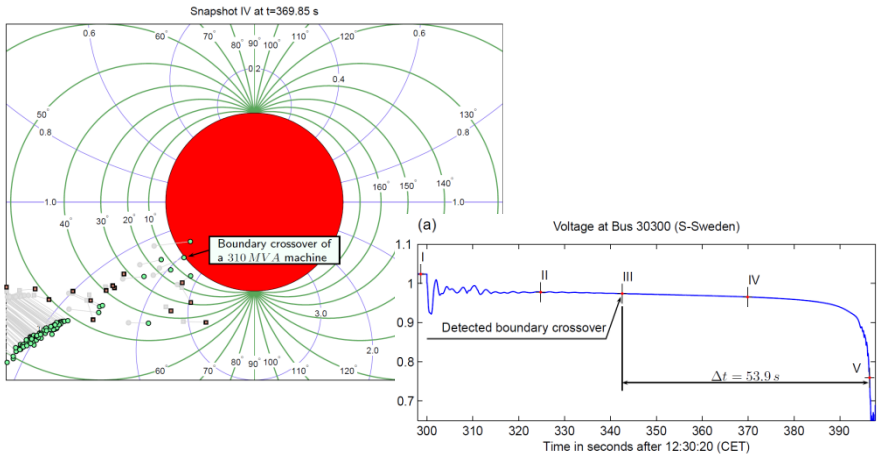
The Nordic32 Test System



- Well known test system
  - Proposed by Cigre TF 38-02-08
  - Widely used in scientific literature
- Use of Nordic32 in SOSPO
  - Represent future scenarios
  - Replace SG's with wind farms
  - Several scenarios with different level of wind penetration
  - Real-time demonstration of R&D results using the RTDS and the SOSPO SW-platform

World-Record in Fast Real-time Security Assessment of Electric Power Systems





Conventional approaches

- Off-line analysis
- Assessment times of 5 – 15 minutes
- Insufficient for systems with high share of stochastic energy sources
- Detailed and accurate models needed

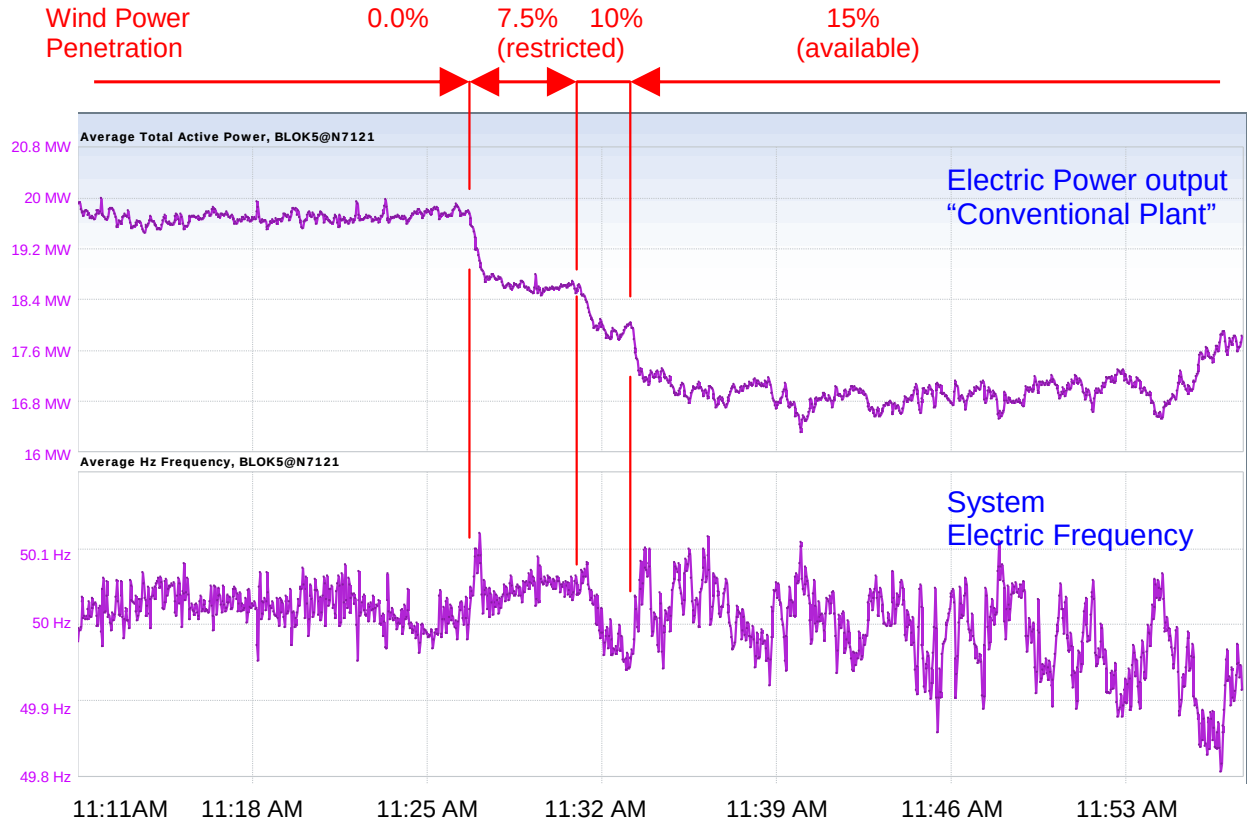
Developed approach

- Real-time assessment of the operating condition
- PMU's are an enabling technology
- Analytical approach
- Assessment time 2.5 ms @ 7917 nodes, 1325 gens
- 2003 SW-DK blackout -> ≈80 s warning; no blackout
- Optimal remedial actions can easily and fast be identified

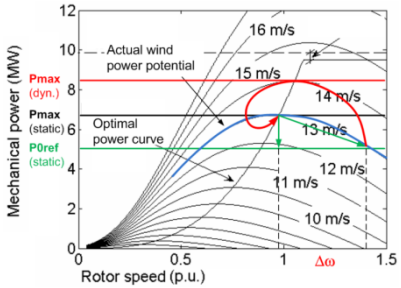
Refs: *International Journal on Power and Energy System*, 2012
Patent No. 111681113.6 – 2207
Patent No. EP11195960.7

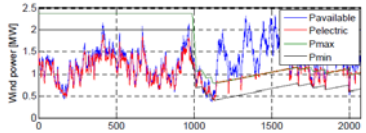
Coordinated Frequency Controllers for Wind Power Plants

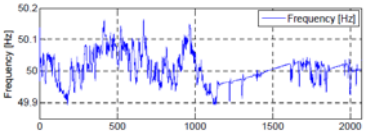
Real-life tests in Bornholm power system



Islanding experiment 17 September 2009.







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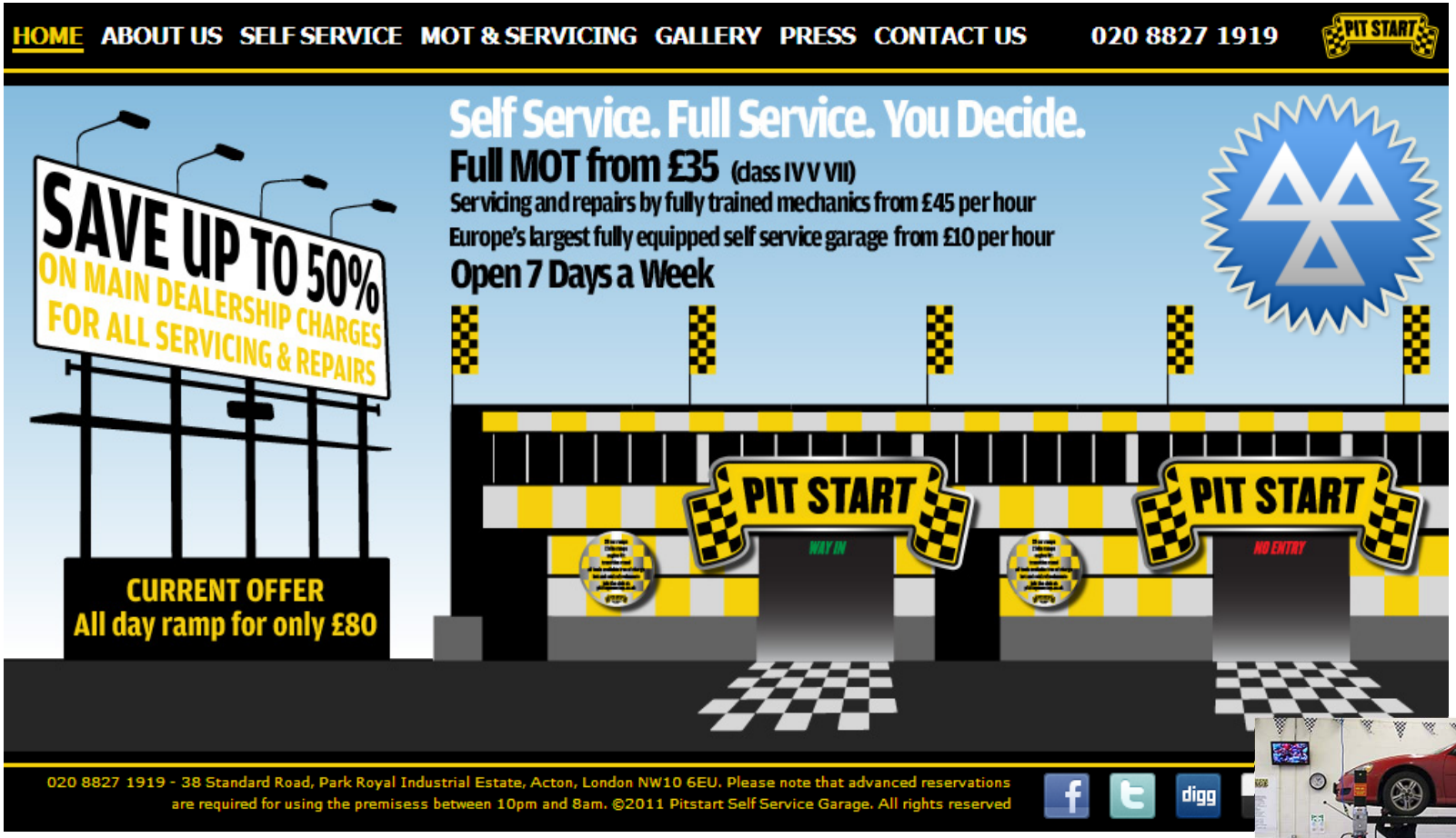
Refs: *9th International Workshop on Large-Scale Integration of Wind Power*, 2011
Patent No. US20120161444, 2011

PowerLabDK Open Access
Self Service Garage Model



Self Service. Full Service. You Decide.

PowerLab - a Dynamo for Interaction and Collaboration between Facilities, Students, Researchers and Industry

fugleperspektiv sydøst

Laying of the Foundation Stone for PowerLab phase 2

9 September 2014

Thank you for the attention!

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